number 02
March 31 2005
cnes
ON EARTH, IN SPACE
E-SPACE & SCIENCE
THE SCIENTIFIC BULLETIN OF CNES, CENTRE NATIONAL D'ETUDES SPATIALES

The “Zigzag” effect

Source

Experimental Evidence for a Zigzag Bifurcation in Bulk Lamellar Eutectic Growth

Silvère Akamatsu, Sabine Bottin-Rousseau, Gabriel Faivre.
Physical Review Letters 93, 175701 (2004)

"Zigzag" dynamics of lamellar eutectics.

An eutectic is an alloy, the solid state of which consists of a mixture of two phases (see below) of different crystal structures and chemical compositions. Eutectic alloys have a much lower melting points than the pure components, hence their widespread use in industrial processes such as welding and soldering. Moreover, the crystal phases that form the eutectics are usually arranged in very thin lamellar or fibrous patterns, which endow the solid with outstanding mechanical and physical properties.

The interlamellar spacing of directionally solidified eutectics is usually of a few microns for a solidification speed of a micron per second, and decreases as the solidification speed increases. Nanostructured materials could be grown at solidification speeds on the order of a centimetre per second, in principle, but this process meets with theoretical and practical difficulties, the main problem is that, for some unknown reason, lamellar eutectic patterns are usually divided into irregular blocks by linear « faults », the spacing of these faults is about ten times the lamellar spacing.

From a fundamental standpoint, this is a problem of "nonlinear dynamics in two dimensions". A solidification microstructure is the trace left behind in the solid by the formation of an out-of equilibrium dissipative structure, or pattern, at the solid-liquid interface during the growth of the solid. In order to understand such phenomena, it is necessary to study their spatio-temporal evolution in real time and to monitor the evolution of the solid-liquid interface through the liquid, and to separate its image from the image of the underlying solid. Our experimental setup allows us to perform such observations in model transparent eutectic alloys.

To minimise the perturbations generated by the convection flows in the liquid, this experiments will be performed later in microgravity. The European Space Agency (ESA) and CNES are studying various options to perform these experiments onboard the International Space Station (ISS).

Using semi-thin (400 µm-thick) samples, the authors were able to obtain, on earth, preliminary results about the morphological instability that basically limits the stability of lamellar eutectic patterns.

[…]

E-SPACE & SCIENCE
THE SCIENTIFIC BULLETIN OF CNES, CENTRE NATIONAL D'ETUDES SPATIALES

"Zigzag" dynamics of lamellar eutectics (ctd.)

Affiliations

Institut des NanoSciences de Paris (formely known as Groupe de Physique des Solides), University Paris 6 , Campus Boucicaut, 75015 Paris, France

Very probably, this instability is the so-called zigzag bifurcation, which has been previously observed in other two-dimensional dynamical systems, but never before in eutectic growth.

This result does not enable us to explain the large-scale «faults» of eutectic patterns yet, but strongly supports The authors' view that these faults too are part of the intrinsic nonlinear dynamics of these patterns, in contradiction with the common hypothesis that they are induced by crystallographic defects of the underlying solid.

This article was published in the issue of October 22d, 2004, of the specialized American scientific journal "Physical Review Letters".

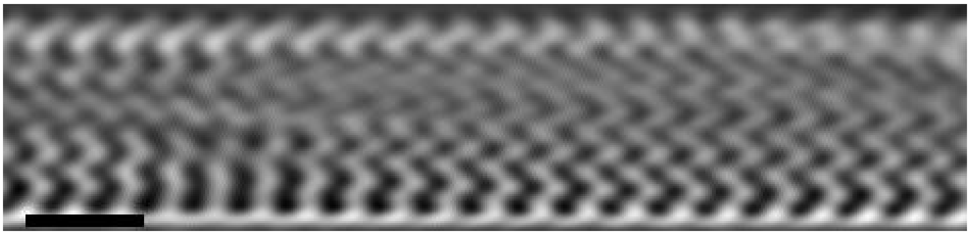

Photo of the interface during solidification
Real-time observation of a solid-liquid interface during the directional solidification of the model transparent eutectic alloy (CBr4-C2Cl6). The interface, which is advancing towards the observer at the imposed rate of 0.5 µm/s, is observed obliquely through the liquid with the help of an appropriate optical setup. Hence the image is reduced by a factor of 0.35 in the vertical direction. This photograph shows the primary lamellar pattern of the interface undergoing a secondary « zigzag» instability. Scale bar: 50 µm
© S. Akamatsu

DSMA
The instrument DSMA (**D**irectional **S**olidification of **M**ultiphase **A**lloys) allows the real-time observation of the solidification fronts of multiphased transparent solids in bulk samples with a resolution on the order of a micrometer. The growth front is observed in oblique view through the liquid. The thermodynamical study of transparent non-faceted multiphase alloys is undertaken by a German group (ACCESS, Aachen) and completes the observations. Within the frame of this cooperation, the French participation is sponsored by the CNRS and the CNES.

[...]

number 02
March 31 2005

cnes ON EARTH, IN SPACE

E-SPACE & SCIENCE
THE SCIENTIFIC BULLETIN OF CNES, CENTRE NATIONAL D'ETUDES SPATIALES

What does mean "phase"?

Contact

E-Mail
akamatsu@gps.jussieu.fr

Phone
+33 1 44 27 63 99

A thermodynamical «**phase**» is an assembly of a large number of identical atoms, or molecules which is homogeneous on a macroscopic scale when submitted to uniform temperature and pressure at its boundary. A pure substance usually has a single gaseous, and a single liquid phase, but may have, depending on temperature and pressure, several different solid phases corresponding to different arrangements of the molecules in the crystal. This solid-state « polymorphism » is a very common phenomenon. For instance, pure iron is in a body centered cubic phase (called « ferrite ») at room temperature, but in a face centered cubic phase (called « austenite ») at 1000°C. The different phase of the carbon are also well known and everybody make a difference between diamond and graphite.

In the case of alloys (multicomponent systems), several phases may also exist in the liquid state. For instance, a mixture of water and oil undergoes a spontaneous separation into two different liquid phases, one rich in water, the other rich in oil. The so-called « eutectic » alloys exhibit a similar phenomenon of “separation” (called demixtion) into two phases of different concentrations during solidification. In fact, this is the case of most alloys inside certain intervals of concentration.

Gabriel Faivre

+ about CNES

www.cnes.fr

+ about the ISS

http://www.esa.int/

E-space&Science keeps you informed about results on CNES supported scientific pragrammes

Publishing Director: **Yannick d'Escatha** ■ Managing Director: **Arnaud Benedetti** ■ Chief Editor : **Michel Viso** ■ Assistant Editor : **Myriana Lozach** ■ Circulation: **INIST diffusion** ■